Figure 6. Storm Conditions During Atlantic City Tests

BIBLIOGRAPHY

~~Ocean Wave Spectra Proceedings of a Conference on Ocean Wave Spectra, Easton, Maryland, 1961, Prentice Hall, 1963.~~

~~Pierson, W. J., Jr., G. Neumann, and R. W. James, Practical Methods for Observing and Forecasting Ocean Waves by Means of Wave Spectra and Statistics, H.O. Pub. 603, U. S. Navy Hydrographic Office, 1955.~~

~~Proceedings of the Conference on Automatic Data Handling for Oceanographic Observations, Ref. No. 60-18, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, 1959.~~

~~Tucker, M. J., The Accuracy of Wave Measurements Made With Vertical Accelerometers, Deep Sea Research, V, 185, London, 1959.~~

WAVE MEASURING INSTRUMENTATION FOR FIELD INVESTIGATIONS ON BREAKERS

by Alfred Führböter[1] and Fritz Büsching[2]

ABSTRACT

As water-air-interaction cannot be simulated completely in a model, laboratory investigations on breakers can only be reliable to a certain extent. This is why comprehensive field investigations are necessary; a program of such field measurements was started on the isle of SYLT/NORTH SEA in 1971.

The measurements analyzed were carried out in the surf zone during a severe storm surge.

The measuring devices consisted of a two component electromagnetic current meter and a wave meter placed on the beach at a distance of 85 m from the coast line and another wave meter located 15 m offshore.

In order to be able to use different analyzing methods the outputs of the measuring devices were fed simultaneously to a magnetic tape recorder.

For the purpose of data processing on a PULSE HEIGHT ANALYZER the signals had been chopped by a frequency of 20 kilocycles. Thus the stochastic process could be displayed on a scope as histograms representing 10 minutes real time measuring periods.
From the histograms statistical parameters are obtained to a high degree of accuracy.
For the correlation of water levels and orbital velocities POWER SPECTRA, CROSS POWER SPECTRA, TRANSFER FUNCTIONS and COHERENCE FUNCTIONS are calculated by the use of a FOURIER ANALYZER.

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INTRODUCTION

Based on the secured results of the mechanics of similitude (model laws of FROUDE, REYNOLDS a.o) in many cases it is possible to transfer the results of model investigations to Nature and thus on a model knowledge is obtained with a relatively low expenditure. It is a pity that this does not apply to the research of the surf. Theoretical treatments are still less suitable for the description of the processes in the surf zone.
Contrary to the "weak interactions" represented by the input of energy from the atmosphere and the dissipation of energy owing to internal and bottom friction (see e.g. HASSELMANN 1968), already white capping in the open sea is a strong interaction with a high consumption of energy which offers high difficulties to theoretical treatment (HASSELMANN 1968 and 1973).
Already for the stationary flow in the case of the hydraulic jump it is possible to show, which considerable influence is exercised by the surface forces on the transformation of energy through the thorough mixing of air (BRETSCHNEIDER 1965). The law of similitude of WEBER is applicable to this process which, - if in the model the same liquid is used as in Nature - can be accomplished with in the scale 1:1 only, thus in the natural scale.

Through the surface forces (surface tension), the conversion of energy is brought about by the formation of a water-air mixture which, as in the case of the hydraulic jump in the stationary flow (BRETSCHNEIDER 1965), brings decisively about the transformation of energy in surf zones. No bottom friction is able to produce such transformations of energy over such a short distance.

Already LAMPRECHT (1955) and i.o. PRESS and SCHRÖDER (1966) have pointed to the importance of the formation of a water-air mixture for the energy regime in the surf zone. It is possible to prove by means of simple linear set-ups that the conversion of energy in the surf zone takes place almost exclusively as a consequence of the interaction at the surface (water/air) and not due to bottom friction (FÜHRBÖTER 1970 and 1971).

The signs are increasing that in surf actions the theoretical difficulties which result from the mechanism of similitude for the transference from the reduced models into Nature, as the model waves in the laboratory are increasingly reduced, the difficulties are preponderant which oppose the immediate theoretical treatment. That need not

diminish the value of model experimenting and theoretical treatments - but primary remain the processes in Nature to be explained, and there the model and/or the theory have to be accommodated to Nature and not inversely.

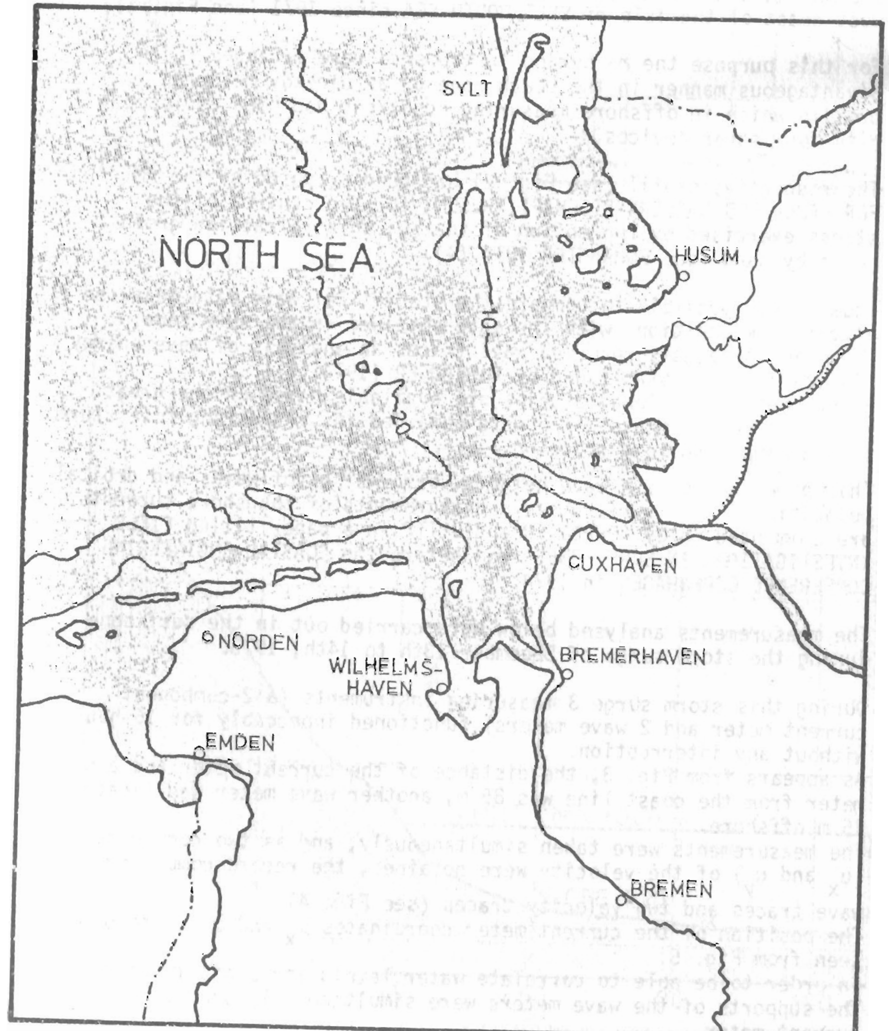

Fig.1 THE GERMAN BIGHT

MEASURING PROGRAM AND FIELD SAMPLING ARRANGEMENT

In order to get information regarding the variation of wave characteristics and the sediment transport in the vicinity of the shore, a great many measurements have been performed on the west coast of the isle of SYLT/NORTH SEA since 1971 (see Fig. 1).

For this purpose the measuring instruments were arranged in an advantageous manner in the beach zone of an already measured profile which in offshore measuring positions had been equipped with four sonar devices.

The respective profil (see Fig. 2) had been prepared by the AMT FÜR LAND- UND WASSERWIRTSCHAFT, HUSUM, for the control of the stress exercised by the motion of the sea on a refraction groin built by sand (see FÜHRBÖTER 1974 (1)).

Thus it was possible to compare the statistical wave data measured at offshore positions with the data obtained in the surf zone. From simultaneously recorded wave traces an analysis of wave energy dissipation was established by FÜHRBÖTER (1974 (2)).
At present 2 additional studies are available based on the great number of measurements which were obtained in 1973 during five storm surges happening in succession.

This paper deals with wave heights, deformation of waves and orbital velocities in the surf, whereas measurements of longshore currents are commented on by FÜHRBÖTER and DETTE in a paper titled FIELD INVESTIGATIONS IN SURF ZONES read before the COASTAL ENGINEERING CONFERENCE COPENHAGEN in 1974.

The measurements analysed below were carried out in the surf zone during the storm surge of December 13th to 14th, 1973.

During this storm surge 3 measuring instruments (a 2-component current meter and 2 wave meters) functioned inpeccably for 16 hours without any interruption.
As appears from Fig. 3, the distance of the current meter and a wave meter from the coast line was 85 m, another wave meter was located 15 m offshore.
The measurements were taken simultaneously, and as two components (u_x and u_y) of the velocity were obtained, the record comprised two wave traces and two velocity traces (see Fig. 4).
The position of the current meter coordinates u_x and u_y is to be seen from Fig. 5.
In order to be able to correlate water levels and orbital velocities, the supports of the wave meters were simultaneously used for the current meter.

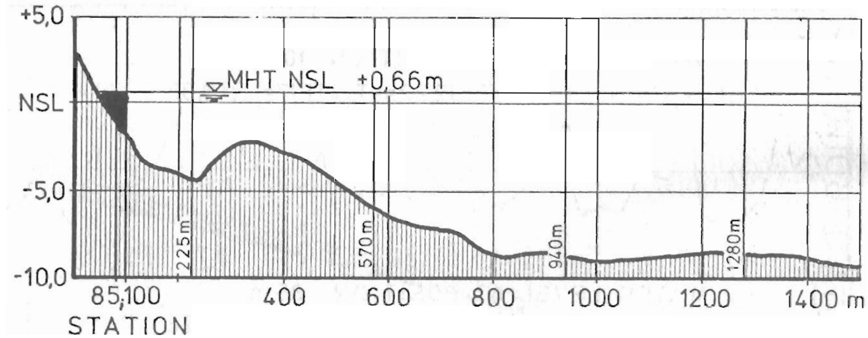

Fig.2 MEASURING PROFILE

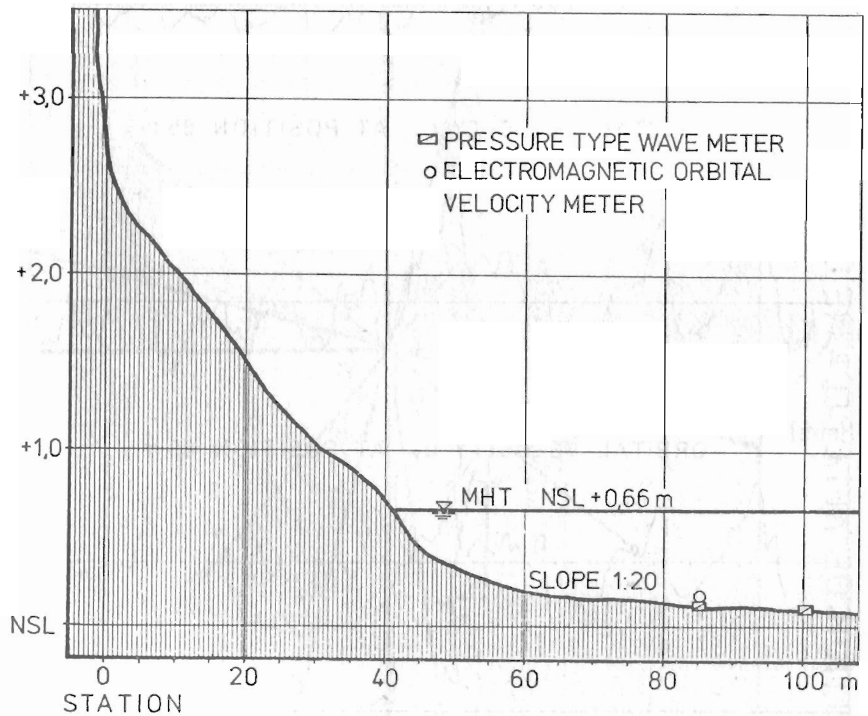

Fig.3 FIELD SAMPLING ARRANGEMENT FOR VELOCITY AND PROFILE DATA

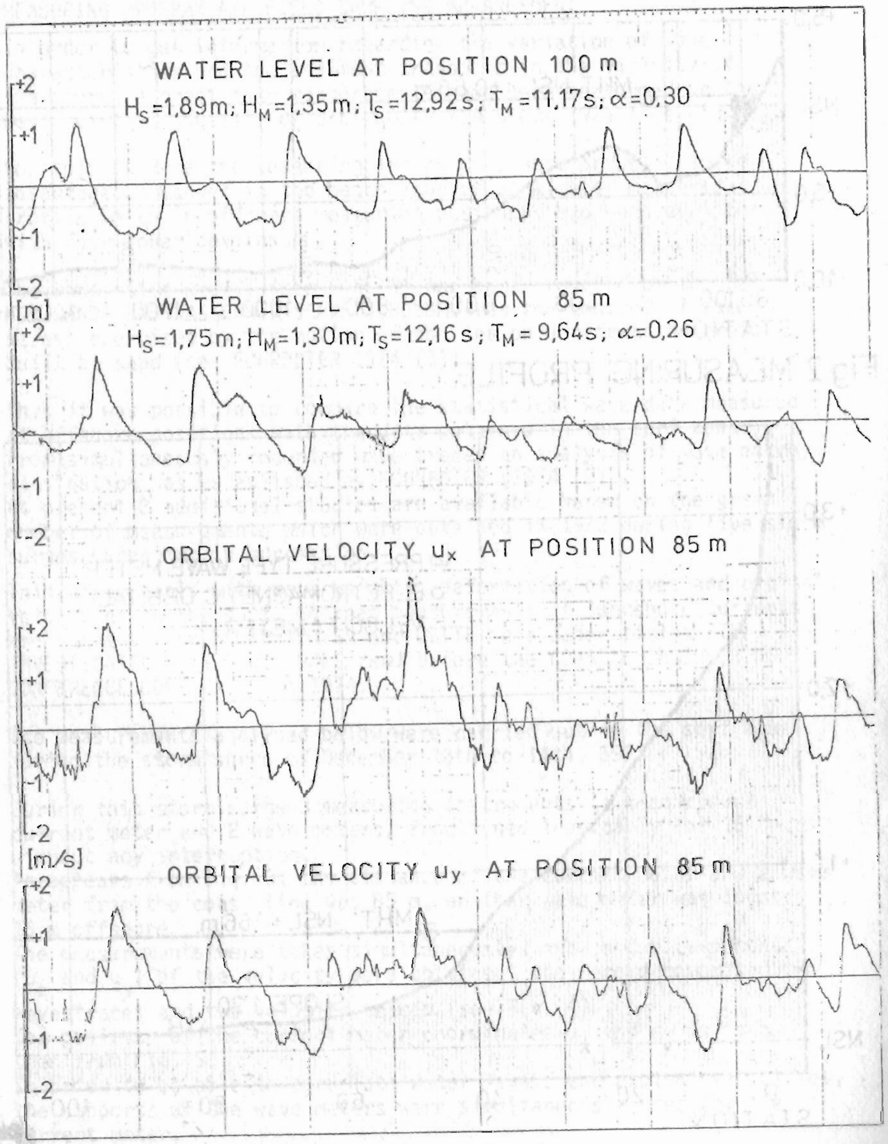

Fig.4 SIMULTANEOUS RECORDINGS ON 14 DEC,1974

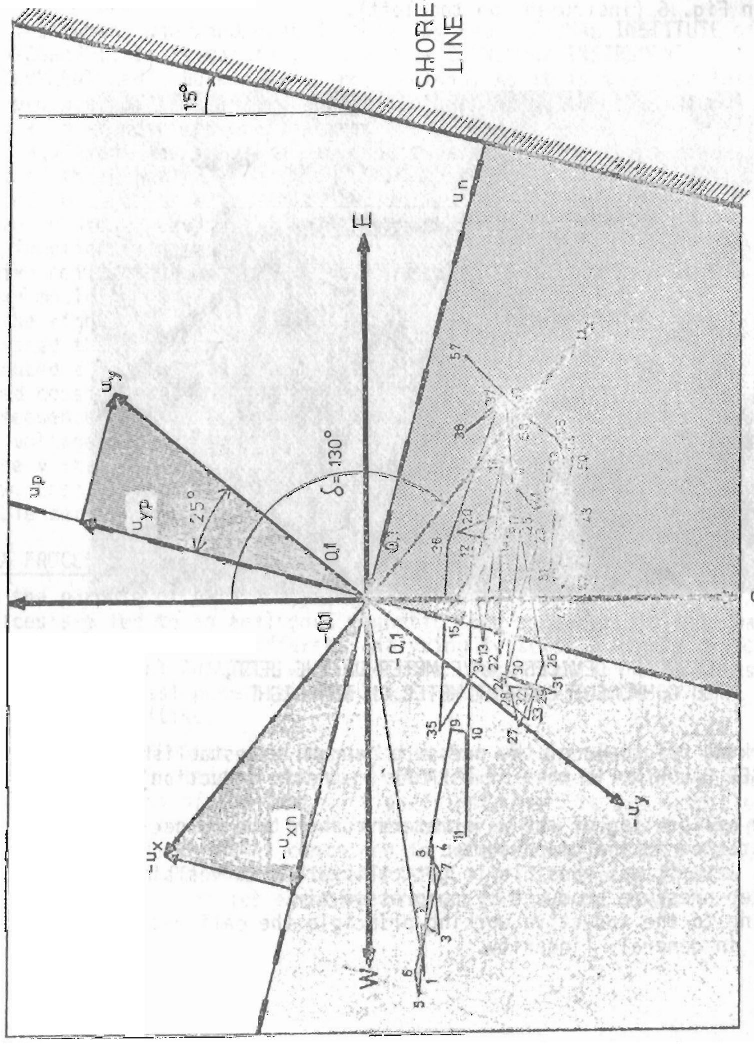

Fig.5 POSITION OF VELOCITY METER AND SYSTEM OF COORDINATES

MEASURING INSTRUMENTATION:

WAVE METERS

Pressure type wave meters for the wave profile measurement according to the water depth $0.3 \leq d \leq 3.5$ m.
This type of devices was enclosed in waterproof housings attached to steel supports which were located on the beach as shown in Fig. 6 (instrument on the left).

Fig. 6: MEASURING DEVICES; WAVE METER ON THE LEFT, TWO COMPONENT CURRENT METER ON THE RIGHT

The working principle of the pressure gauges, as established by HOTTINGER BALDWIN, is that of FARADAY (magnetic induction).

For the calibration of the wave meters rubber tube connections were attached to the diaphragms.
In this way, it was possible to get calibration curves simulating the water pressure produced by compressed air.
According to the inductive working principle the calibration curves showed, in general, linearity.

It turned out that the influence of the temperature could be neglected for the evaluation of the wave profile.
The signals of the pressure pickups were fed via cable to carrier frequency generators and after having been amplified monitored on a viscorder.

VELOCITY METER

The instrument used had been designed by the NATIONAL INSTITUTE of OCEANOGRAPHY. It is manufactured by the COLNBROOK INSTRUMENT DEVELOPMENT Ltd., Buckinghamshire, England. As it is supposed that the producer of this instrument is also attending the symposium, only a brief description is given.
This equipment was actually designed as a ship's log for the measurement of the velocity of a ship in two components. That is why it seemed to be quite suitable to be applied for the measuring of currents under heavy swell conditions.
Its function is based on the principle of electromagnetic induction. A wire coil with a vertical axis is encased in a flat ellipsoidal epoxy moulding fixed to the end of a spar (see Fig. 6, instrument on the right).
Provided that an electric current passing through the coil had produced a magnetic field, the conducting water passing the steamlined housing acts like a wire moved in a magnetic field, and as a consequence a potential gradient is produced.
The voltages generated are picked up by two pairs of electrodes; these voltages are proportional to the two components of the water flow. Special arrangements are made inside the electronics to get a stable zero.

DATA PROCESSING

For the purpose of data analyzing the signals from the measuring devices are fed to an analogous magnetic tape recorder. In this way it was possible to use different analyzing systems. A highly dissolving PULSE HEIGHT ANALYZER was used as a classification unit so as to obtain the highest possible accuracy in the determination of the statistic quantities.

A FOURIER ANALYZER was used in addition for the appraisal of the processes taking place in the surf according to their mutual dependencies. By means of the last mentioned instrument it was possible to investigate, on the one hand, the motion of the sea in the surf as regards the frequencies contained in it and, on the other hand, to infer from CROSS POWER SPECTRUM, TRANSFER FUNCTION and COHERENCE FUNCTION any dependencies existing between two signals transmitted at the same time.

DATA PROCESSING IN USING A PULSE HEIGHT ANALYZER

The data processing equipment is shown in the block diagram of Fig. 7.

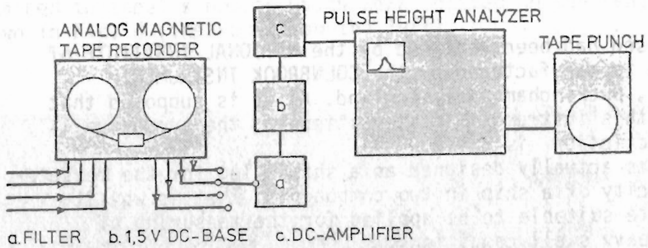

Abb. 7: BLOCK DIAGRAM

The signals (≤ 1 volt) taken from the magnetic tape had, first of all, to be passed through a filter, where disturbance frequencies $f > 3$ Hz were filtered off and longperiodic variations (DC-component of the signal) were suppressed.

As the 400-channel PULSE HEIGHT ANALYZER produced by FRIESEKE and HOEPFNER could be fully modulated only with the voltages of one sign (0 down to 20 V DC), it was necessary to provide, on the one hand, the signal with a base voltage (from a battery) and, on the other hand, to have the analyzer preceded by a DC amplifier.

A CHOPPER was incorporated in the analyzer itself which chopped the respective signal with a frequency of 20 kilocycles. These voltage values of $\Delta t = 50\ \mu s$ duration were offered, according to their amount, to the corresponding channel of the classification unit (- 20 V = 400 channel) and there summed up through the counting duration.
The counting process could be observed on a scope during the chosen duration of analysis $\Delta t = 10$ minutes.

In using a DC-source it has been proved that the measuring system had a very high degree of linearity.

Accordingly 23.7 channels correspond to a voltage of 0.166 volts and the latter figure in its turn to a velocity of 1 m/s or 1 m WG respectively.
The records of the magnetic tape were treated in such a way that, alternating 10 minutes of measuring time and 20 minutes interval, a histogram was obtained every half hour. An example of a sequence of histograms is plotted on Fig. 8.
For the further treatment, the contents registered by the different channels of the classification unit were transmitted through perforated tapes.
By the use of a computing program the statistical figures MEAN, MEAN DEVIATION, STANDARD DEVIATION a.o. have been determined for the investigated time functions.

DATA PROCESSING IN USING A FOURIER ANALYZER

Spectrum analysis is one of the most used methods, but it has the disadvantage to consume a long computer time. That is why a HEWLETT PACKARD FOURIER ANALYZER working on the COOLEY-TUKEY-ALGORITHM (Fast Fourier Transform) was used.

There is no sufficient space left here to deal with the basical mathematics of spectrum analysis; the spectrum functions and the accuracy of the equipment are, however, commented on in detail by BÜSCHING (1974), as regards these measurements.

In using a Fourier analyzer it was possible to process simultaneously two signals transmitted from the measuring devices.
As it was one of the objects of the study under consideration to establish the relations between orbital velocities and wave profile data in addition to power spectra (energy spectra), Cross Power Spectra, Transfer functions and Coherence functions of the signals transmitted by the wave meters and the current meters were plotted down.
An example is shown in Fig. 9.

For analyses of sea motion it is sufficient according to KAMPHUIS (1969) to take into acount processes with periods $T \geq 0,5$ s.

In the present case a maximum frequency of 3.125 cps. corresponding to a minimum period of $T_{min} = 0.32$ s < 0.5 s was presupposed owing to the stepped adjusting ranges at the Analog-to-Digital Converter (ADC) of the Fourier Analyzer.
A minimum frequency equal to the NYQUIUST frequency was chosen so that the ALIAS error just missed to occur and the sample interval Δt had the minimum amount possible for the chosen input values.

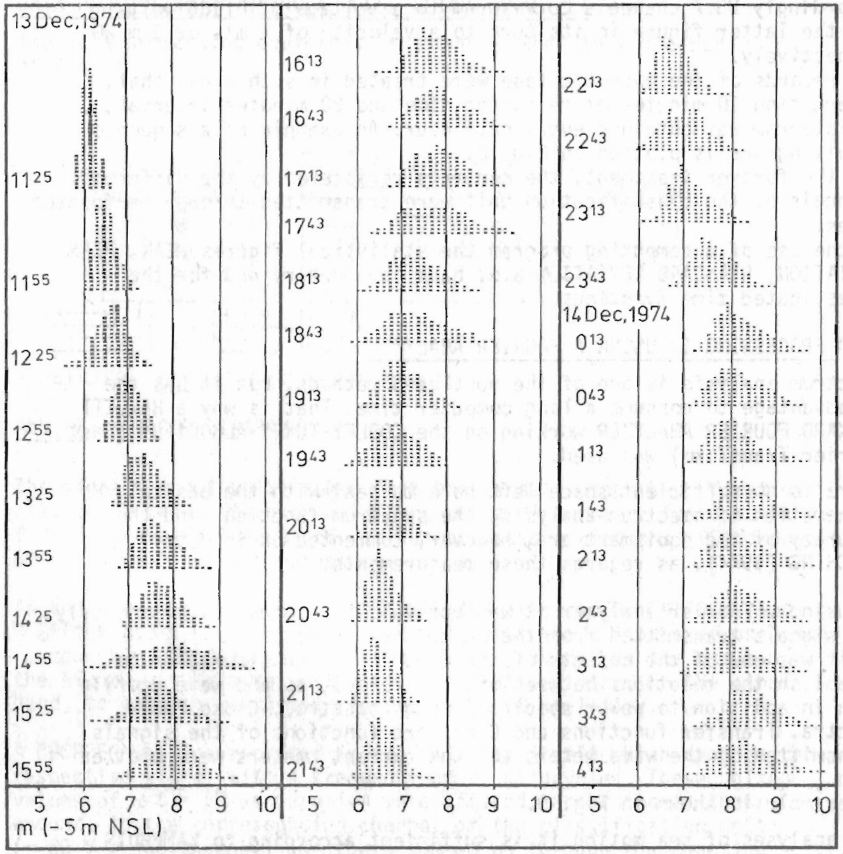

Fig.8 SEQUENCE OF HISTOGRAMS
FROM WHICH MEAN RECORD WATER DEPTHS Z_3 WERE CALCULATED.
EACH HISTOGRAM REPRESENTING 10MINUTES MEASURING PERIODS.

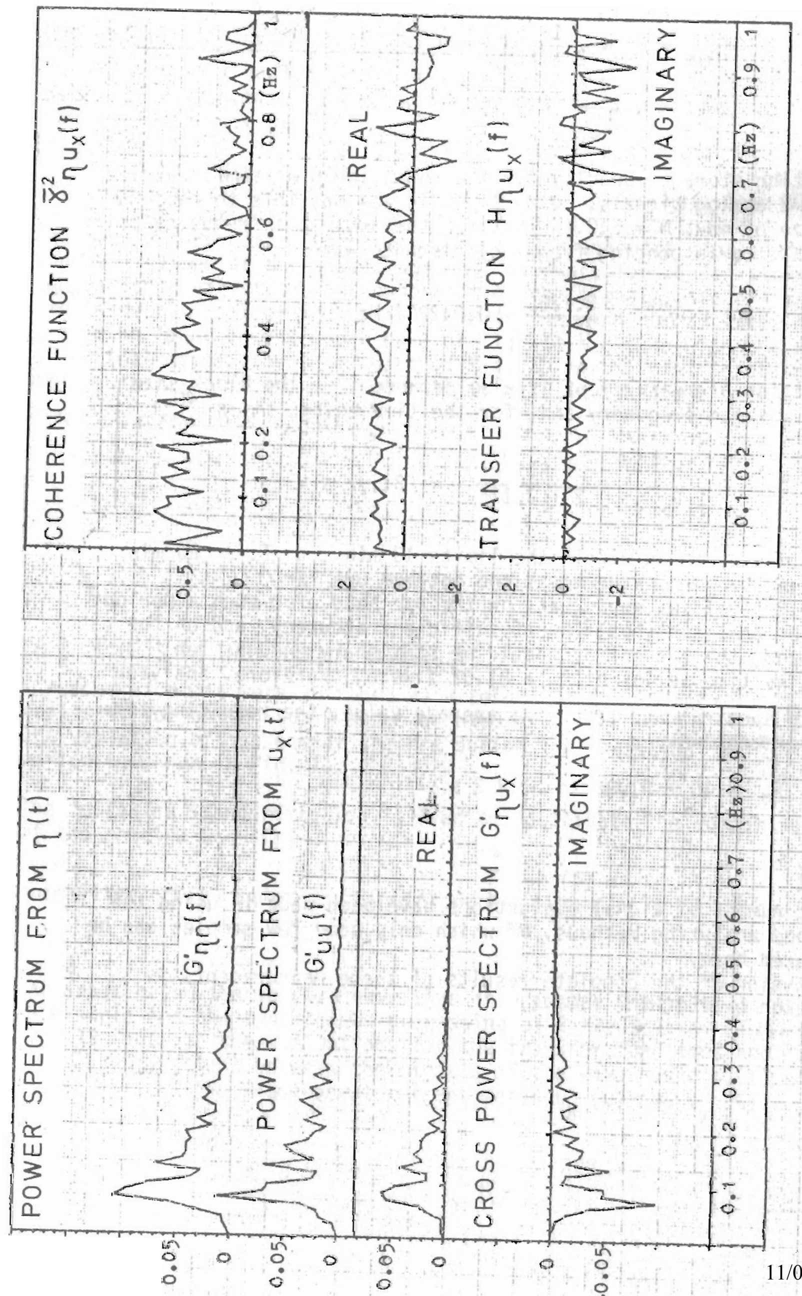

Fig.9 SPECTRUM FUNCTIONS FROM WATER LEVELS $\eta(t)$ AND ORBITAL VELOCITY COMPONENT $u_x(t)$ AT MEASURING POSITION 85 m

$$F_{max} = F_N = \frac{1}{2\,\Delta t}$$

$$\Delta t = \frac{1}{2\,F_{max}} = 0{,}16\ s$$

The existing storage capacity for the computing programme, carried out with 2 analog signals, being 16 K, it was possible to chose a block size of max. N = 512 so that for the available frequency point set N/2 the corresponding frequency distance was

$$\Delta f = \frac{F_{max}}{N/2} = \frac{3.125}{256} = 0{,}012207\ Hz$$

The duration of measurement is also dependent on the block size and the maximum frequency and, for the time being, it is

$$T_R' = \frac{N}{2\,F_{max}} = \frac{512}{2 \cdot 3.125} = 81{,}92\ s$$

A measuring duration within the limits 10 min. $\leq T_R \leq$ 20 min. is however to be considered as the optimum one for the analysis of sea waves, as, on the one hand, for such a period a Fourier analysis should be of sufficient accuracy, and on the other hand, the sea motion should be stationary enough. Ten successive time series of T_R = 81,92 s were, therefore, analyzed for each spectrum and taken the average value, the resulting time of measurement was:

$$T_R = 10 \cdot 81{,}92\ s = 819{,}2\ s$$

RESULTS

A great number of signal evaluations have been made in using the explained analyzing methods, of which only some few samples can be reproduced here.
A discussion of the complete results of these measurements is undertaken by BÜSCHING (1974).

SOME RESULTS OF THE PULSE HEIGHT ANALYSIS:

The pulse height analysis of the transmitter outputs resulted in a number of histograms, each of which representing a 10 minutes real time measuring period.
They were used to find the standard deviations σ for the determination of the characteristic wave heights. For the measuring position 85 m and 100 m, the characteristic wave heights $H_{m_0} = 4\,\sigma$ have been plotted in the lower part of Fig. 10 on the left.
The mean record water depths and the net currents are represented by the mean values of the histograms. As, however, for these values the longperiodic variations (DC component of the signals) are of importance, the respective filter had to be removed. The mean record water depths z_3 are to be found in the upper part of Fig. 10 together with the records of a tidal gauge. The lower part of Fig. 10 on the right contains the magnitudes $|u_{res}|$ of the net currents as well as the coast normal and parallel components u_n and u_p.

SOME RESULTS OF THE FOURIER ANALYSIS:

A number of plots were obtained as a result of the FOURIER Analysis, for which Fig. 9 shows an example.
The variation of the energy spectra during the investigation period is shown in Fig. 11.

The following standardization is used to facilitate the comparison of the spectra Gnn (f):

$$\text{Normalized Energy Spectrum} \quad G'nn(f) = \frac{\int_0^{\infty} Gnn\,(f)\,df}{\sigma_n^2} = 1$$

The areas below the spectra have thus in any case the value 1. As an example for the synchronous processing of 2 transmitter signals, Fig. 12 contains the evaluations for the transfer functions and coherence functions between the signals of the wave gauge η (t) and the signals of the 2-component current meter u_x (t) and u_y (t).

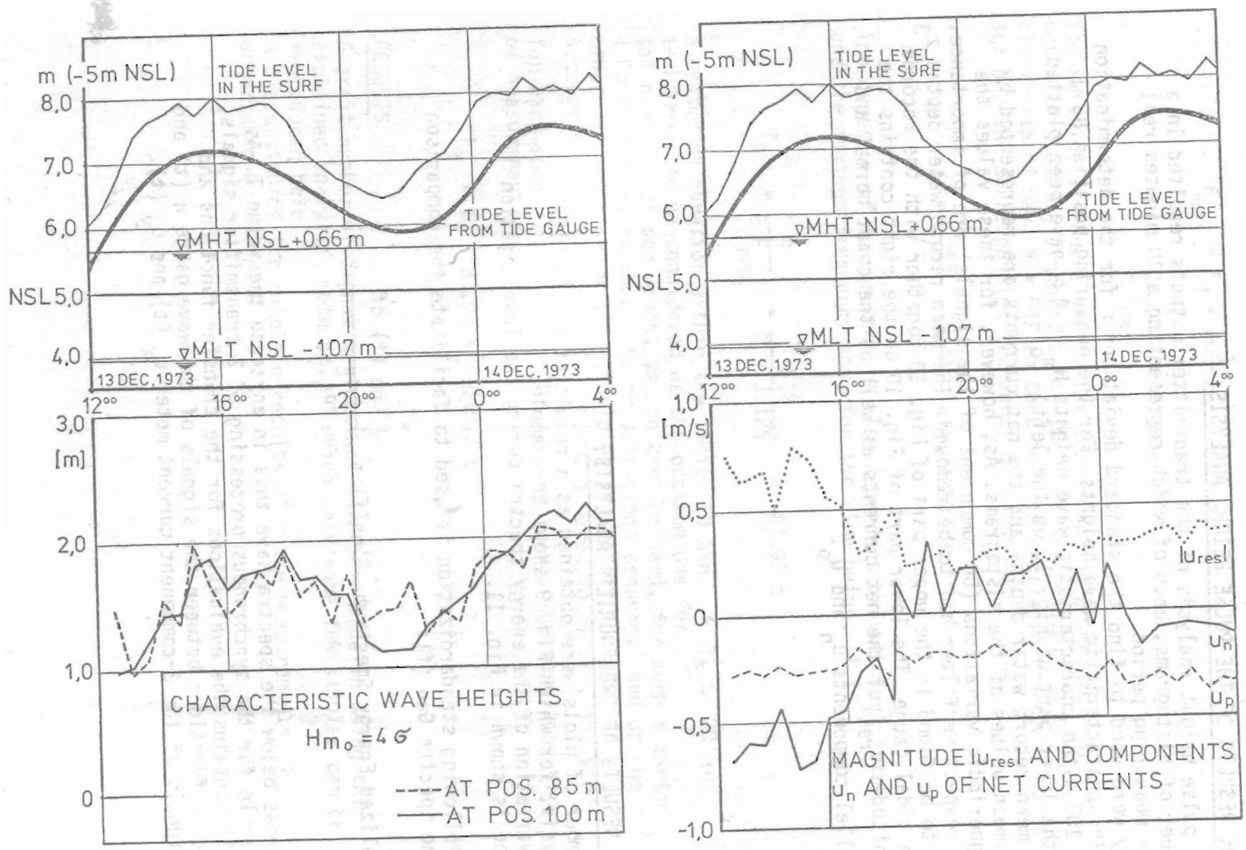

Fig.10 RESULTS OF PULSE HEIGHT ANALYSIS

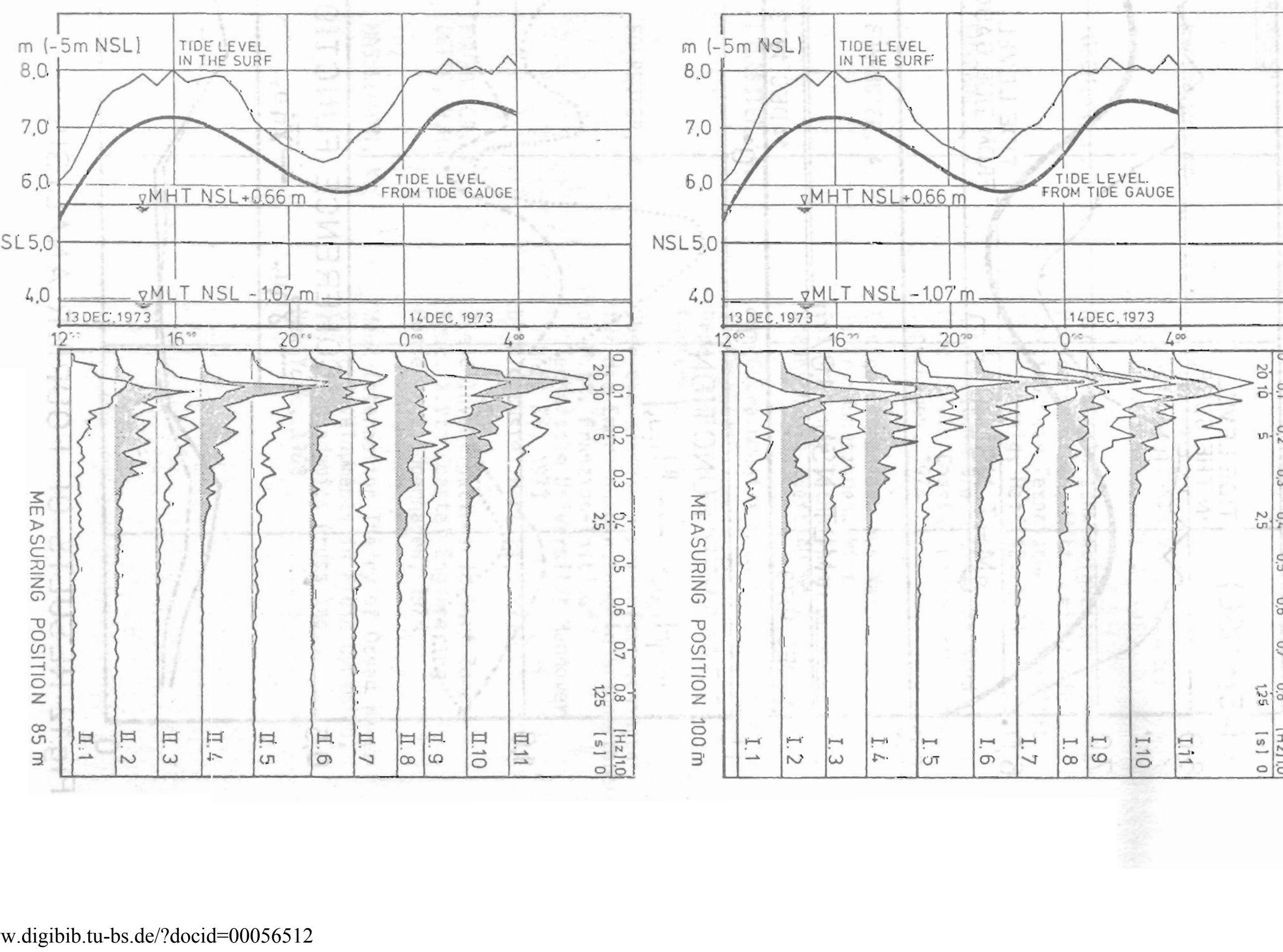

Fig.11 POWER SPECTRA

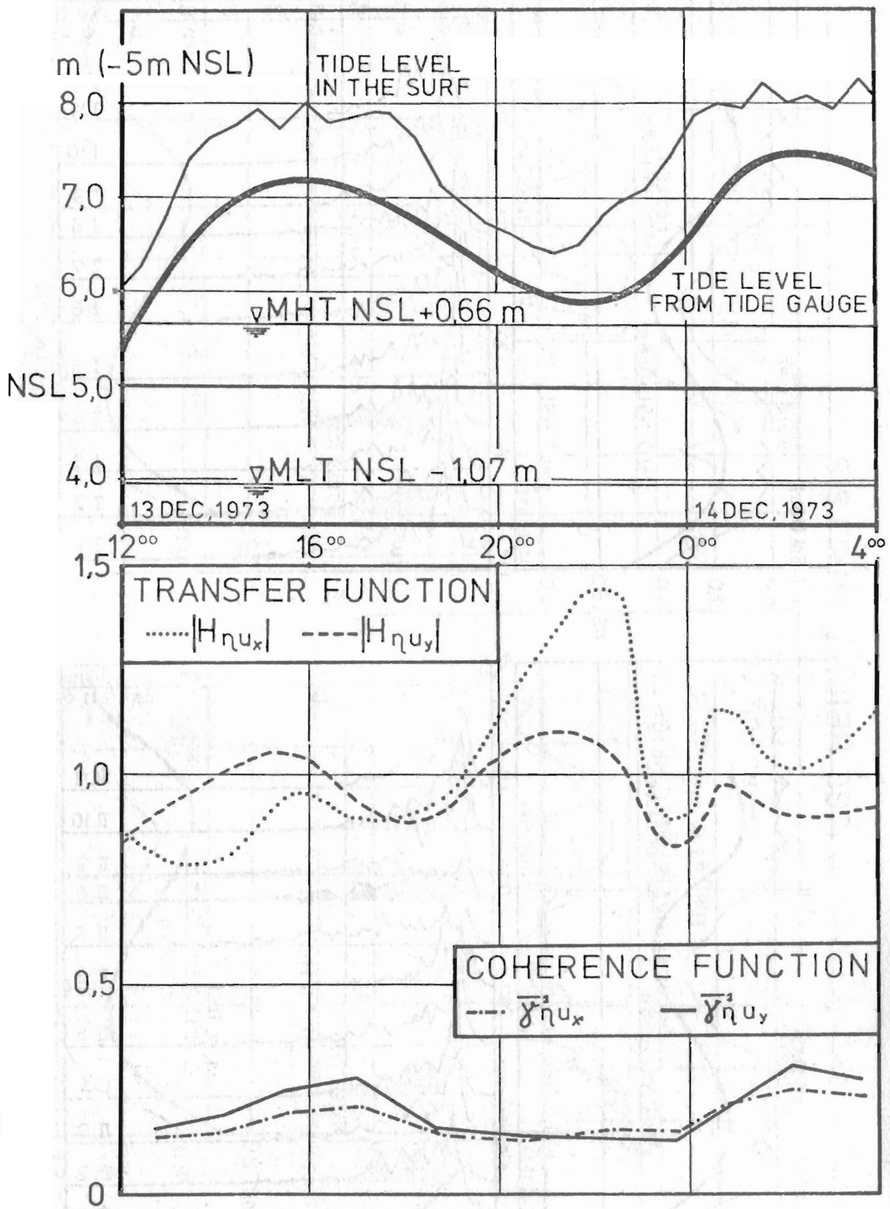

Fig.12 RESULTS OF FOURIER ANALYSIS

REFERENCES:

1. BRETSCHNEIDER, H. — Die Auswirkungen von Oberflächenkräften im wasserbaulichen Versuchswesen Die Bautechnik, Heft 4, 1965

2. BÜSCHING, F. — Über Orbitalgeschwindigkeiten irregulärer Brandungswellen, Mitt. Leichtweiß-Institut der Technischen Universität Braunschweig, Heft 42, 1974

3. FÜHRBÖTER, A. — A Refraction Groin Built by Sand Proc. XIVth Coastal Engineering Conf. Copenhagen, 1974 (1)

4. FÜHRBÖTER, A. — Einige Ergebnisse aus Naturuntersuchungen in Brandungszonen, Mitt. Leichtweiß-Institut der Technischen Universität Braunschweig, Heft 40, 1974 (2)

5. FÜHRBÖTER, A. — Air Entrainment and Energy Dissipation in Breakers Proc. XIIth Coastal Engineering Conference Washington, 1970

6. FÜHRBÖTER, A. — Über die Bedeutung des Lufteinschlages für die Energieumwandlung in Brecherzonen
   a) Mitt. Franzius-Institut Technische Universität Hannover Heft 36, 1971
   b) Die Küste, Heft 21, 1971

7. FÜHRBÖTER, A., DETTE, H.H. — Field Investigations in Surf Zones Proc. XIVth Coastal Engineering Conference Copenhagen, 1974

8. HASSELMANN, K. — Weak-Interaction Theory of Ocean Waves Basic Developments in Fluid Dynamics, Vol. 2, Academics Press Inc., New York, 1968